The Study of Fire Effects on Paleontological Resources at Badlands National Park

THE STUDY OF FIRE EFFECTS ON PALEONTOLOGICAL RESOURCES AT BADLANDS NATIONAL PARK

Final Report

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Abstract

National Park Service policies stipulate that each park with vegetation capable of burning will prepare a fire management plan, and presently Badlands National Park is in the process of finalizing a fire management plan for the park. Fossils are a principle resource of the park and the fire sensitivity of fossils is the focus of this study.

The surface temperatures of fossil specimens and fire behavior characteristics were monitored in prescribed fires on the landscape and in laboratory burns to develop an understanding of the relationship between burning conditions and changes in fossil specimen properties.

Condition of individual fossil specimens

Fossil specimens at each of the study sites showed some surface color changes to a chocolate brown. Fossils that were placed in contact with fuel showed consistent discoloration. The effects were more sporadic in sparse fuel settings (Hams Draw #2 and Prairie Wind #2) with partial discoloration in some specimens (Figure 3).

Discussion of results

There were few differences present in the soil temperature measurements across the study sites. The soil profiles instrumented at the Prairie Wind #1 and both Ham's Draw sites had a thin layer of surface litter while the surface layer of the Prairie Wind #2 site was a thick layer of sod produced by *brome spp.* on the site. The increase in soil temperatures on the Prairie Wind #2 site was the result of both the different thermal properties of the upper soil surface material and the increased fire residence time of the backing fire.

The maximum fossil surface temperatures were of short duration, lasting two seconds or less. Calculation of the exact duration was limited by the two-second sampling interval of the data logging equipment. The most extensive specimen surface changes occurred on the flat grassy expanses where there was uniform fuel distribution and where the specimens were in direct contact with the fuel. All discoloration occurred on specimens that had contact with fuel. Based on field observations, specimens in bare bedrock that were at a distance from fuel or were not in contact with fuel were not affected.

2001 Lab Studies

Introduction

During early August of 2001, the lab phase of the project was conducted at the USDA Fire Sciences Laboratory in Missoula, Montana. A total of seven burns were completed in two days.

Under laboratory conditions, low intensity and low to intermediate rates of spread, the surface temperatures of fossil specimens showed limited temperature increases and no surface discoloration. The results from burns under these conditions showed that only fossil specimens that were in contact with burning fuel showed significant surface temperature increases and discoloration. The laboratory results from burns conducted under high intensity and high rates of spread conditions showed increased surface temperatures and surface discoloration and that the changes in fossil specimen properties were not dependent upon contact with fuel.

In field trials during the spring of 2001, prescribed burn treatments were limited by environmental conditions to low rate of spread and low intensity burns. Under these conditions high surface temperatures and surface discoloration were observed on samples that were in direct contact with fuel. The results support the findings in the lab portion of the study. Samples that were not in contact with fuel did not show surface discoloration or significant surface heating.

Both laboratory and field burns suggest that low to moderate fire conditions have minimal impact on fossil resources except in areas where the fossils are in contact with fuel. The laboratory portion of this study suggests that significant fire effects would be found under high spread rate and high intensity conditions even though there is no fuel contact.

Introduction

In the spring of 2001, staff at Badlands National Park, the Black Hills Fire Use Module and the Midwest Regional Office worked in partnership with researchers from the US Forest Service's Fire Science Lab in Missoula, Montana to determine the effect of fire in a prescribed setting on fossil resources within Badlands National Park. Studies included both research plots contained within prescribed burns conducted in the park and laboratory scenarios at the USDA Fire Sciences Lab.

Previous Work

Badlands National Park is world renown for its fossil resources. Paleontological research began in western South Dakota in 1846 with the discovery of a Brontothere jaw by fur traders while traveling along the Ft. Pierre to Laramie trail (Prout, 1846). Following this discovery, museums and research institutions sent out surveys to the Dakota Territories from the 1850's through the 1880's. Paleontological research has continued on into the present. Every major museum in North America and Europe has White River Collections from Western South Dakota.

Paleontological resources were a major reason for originally establishing Badlands National Monument in 1939, for adding the 133,000acre Stronghold District in 1976, and obtaining National Park status in 1978. The congressional report accompanying the 1929 Organic Act for Badlands National Park described the reasons for setting aside the area as the preservation of a unique geological and eroded landscape and because "vast beds of vertebrate fossil remains a vast storehouse of the biological past."

NPS Management Policies for the year 2001 stipulate that each park with vegetation capable of burning will prepare a fire management plan. The plan will be designed to guide a program that responds to the park's natural and cultural resource objectives.

Within Director's Order 18, wild land fuel complexes are managed to achieve resource benefits and management goals such as hazard fuel reduction, ecosystem restoration and maintaining ecosystem health. One form of hazard fuel reduction is the use of prescribed burns.

The staff at Badlands National Park is in the process of finalizing the park's fire management plan. The plan stipulates that the park implement a prescribed burn cycle spanning 12 years. All of the prescribed burn areas are along park boundaries and use badlands formations as fire breaks.

During the Spring 2000, the park paleontologist began a pilot study evaluating the effects of fire on paleontological resources within a prescribed burn setting. Study plots consisted of tiles coated with heat sensitive paints that were set up along with paleontological specimens either brought in or in situ. The focus was on the Pinnacles

Burn Area that is located on the North Eastern boundary of the Badlands wilderness area.

The study areas were composed of different fuel levels. The following microenvironments were included within the study.

Woody Draw
Bare outcrop up to two feet away from fuel source
Grass covered areas
Sparse fuel areas: grass, forbs and shrubs

The following results were obtained from the Spring 2000 Study. The only specimens affected were in grass and woody draw sites. Post burn analysis of the specimens from these sites showed surfaces with a brown tar build up and some smoke staining. Specimens naturally occurring in areas away from flames were not affected. Because heat sensitive paints are only effective in a situation with a sustained heat source, they were not affected in any of the scenarios listed above. However, it appears that little temperature change is required to still have an effect on the fossil specimens. Several papers outlining proper storage conditions for fossil specimens have echoed this conclusion (Ashley-Smith, 1987; Brunton and others, 1985; Fitzgerald, 1995; Howie, 1978; Howie, 1979; Johnson and Morgan, 1979; Stolow, 1966; Thomson, 1986).

General observations were also made from this preliminary study. Burn patterns were extremely variable. Fires often died out before they reached a grassland/bedrock interface. In high fuel areas, (woody draws and grass cover) the burn was more extensive and complete in coverage. The 2000 burn was a Spring backing fire which primarily burned down hill. It had much less intensity than a head fire.

2001 Field Studies

Introduction

In the spring of 2001, the staff at Badlands National Park received research funds to work cooperatively with the USDA Fire Research Lab in Missoula, Montana. The field

component of this study included 4 study plots that were set up during the Roadside Burn, which occurred on the south side of Rt. 240 between Big Foot Road and Quinn road intersections (Figure 1).

Objectives

The goal of the 2001 field study was to develop an understanding of the fire conditions associated with fossil specimen changes observed during prescribed fires. The fire characteristics measured in the field study would later be duplicated and recreated in the laboratory portion of this study. The type and amount of physical changes in individual fossil specimens provided field validation of our laboratory results.

Methods

Data was collected from four study sites that were representative of the grassland fuel type found at Badlands National Park. Three study sites were located on flat areas dominated by grassland fuels at a loading of approximately 1000 lbs /acre. A fourth site was located in a small draw with a 5 to 10 % slope and was dominated by grass and shrub fuels. The Prairie Wind #1 and Hams Draw #1 sites had continuous ground cover and were not considered natural settings because fossils are normally found in areas with exposed soil and not in areas with continuous grass cover (Table 1).

A fire line was ignited at the edge of each study area and the fire spread though each study site. The fires on the Hams Draw #1 and Prairie #2 were primarily head to flanking fires while the fire on Prairie Wind #1 was a backing fire. The Hams Draw #2 site was ignited at the base of the draw and the fire moved up slope through the shrub and grass fuels.

Study Site	Fuel	Slope (%)	Fire Type	Setting Type
Hams Draw #1	Grass	None	Head fire	Unnatural
Hams Draw #2	Grass/ woody shrubs	5-10	Head fire burning uphill	Natural
Prairie Wind #1	Dense grass	none	Backing fire	Unnatural
Prairie Wind #2	Sparse grass/shrubs	none	Head fire	Natural

Table 1. Study Sites – 2001 Field Burns

Fossil specimens were placed on the ground surface at each site. Small gauge thermocouples were attached to the fossil samples and temperatures were measured on the surface of each specimen. Thermocouples were also used to make temperature measurements on the soil surface and at depths below the soil surface.

Radiant heat flux was measured at the soil surface adjacent to the specimens at each site. Sampling was conducted at two-second intervals for both the temperature and flux measurements.

Results

Burning characteristics

The study plots were burned mid-morning to early afternoon under conditions of low wind speed, moderate temperature and relative humidity. The fires on these study sites were all characterized by low rates of spread and low intensities. Radiant flux measured at the surface of the sites range from 11 to 18 kw/cm^2/sec. The rate of spread was lowest on the backing burn of Prairie Wind #2 site. Flame angles were low and flame lengths were in the 1 to 2 foot range. Overall, there were no significant study site differences noted in flame lengths or intensities of the field burns. Higher rates of spread and flame lengths were observed on other burn units in the late afternoon when wind speed and temperature increased and relative humidity decreased.

Soil Temperatures

Limited temperature changes were measured in the top 5 cm of the soil column on all sites. On the Ham's Draw Sites, the average maximum soil temperature in the top 5 cm of soil was 21.3° C during the burn. This change represents an 11.8° increase in temperature from a pre-burn soil temp of 9.5° C (Table 2).

Soil temperature changes were greater at the Prairie Wind #1 site than the other study sites. The average maximum temperature in the top 5 cm of soil was 208° C and represents a 198.5 °C increase over the pre-burn soil temperature of 9.5 °C. Although the fossils at Prairie Wind #2 site were exposed to fire, the flames did not reach the heat flux and soil temperature sensors.

Site	Surface	0.5 cm	2 cm	3 cm	4 cm	> 5 cm
Prairie Wind 1						
Minimum	9	9	10			9
Maximum	418	321	95			82
Range	409	312	85			73
Hams Draw 1						
Minimum	7		6		6	6
Maximum	232		21		20	13
Range	225		15		14	7
Hams Draw 2						
Minimum	19	13		13		13.7
Maximum	31	22		22		21
Range	12	9		9		7.7

Table 2. Soil Temperatures (°C) – 20001 Field Study

Specimen Surface Temperatures

As shown in Table 3, the greatest specimen surface temperature changes occurred at Prairie Wind #1. Specimens at Hams Draw #1 showed a moderate increases in surface temperatures. Specimens at Hams Draw #2 showed a smaller increase in specimen surface temperatures than Hams Draw #1. The results of specimen surface temperature changes at the Prairie Wind #2 were inconsistent. Three specimens showed only small surface temperature increases and one specimen showed a large increase.

Study Site	Average Maximum Surface Temperature (°C)	Temperature Increase (°C)	Pre-Burn Specimen Temperature (°C)
Hams Draw #1	139	129.6	9.9
Hams Draw #2	61	44.3	16.6
Prairie Wind #1	439.3	416.3	23
Prairie Wind #2	45.3	23.03	22.6

Table 3. Specimen Surface Temperatures – 2001 Field Study

Objectives

Predicting the fire effects on fossil specimens requires an understanding of the factors affecting the heat transfer from a flaming fire front to the surface of the specimens. This lab study concentrated on the relationship of fire effects on fossil specimens with radiant heat flux, rate of spread and flame angle during expected prescribed fire conditions. Environmental conditions that were recorded in the field at Badlands National Park were recreated in the lab in Missoula. However, this provided the opportunity to remove many of the variations found in the field

Methods

Laboratory burns were designed to simulate a range of prescribed burning conditions. 4.5 x 1 meter fuels beds were constructed and burned in a controlled combustion chamber environment at the USDA Fire Research Lab in Missoula, Montana

The burns were conducted on fossil samples from two geologic epochs: specimens of marine invertebrates from the Cretaceous and vertebrates from the Oligocene epoch. A 0.5 x 1.0 meter bed of soil matrix was set up at the end of each fuel bed and was divided into two parts. The fossils were placed on a soil surface of either Pierre Shale or Mudstones from the White River Group (Figure 4).

To simulate the most common fuel types of Badlands National Park, two fuel-loading treatments were created using excelsior and multi-flora rose. Excelsior, which is composed of fine aspen wood shavings, was used as a grass fuel surrogate at 1000 lbs/ acre. Partially dried multi-flora rose shrubs were added to simulate shrub fuel loadings associated with grassland /shrub fuel complex. The addition of this material increased the fuel loading to approximately 1200-1400 lbs/acre. The increase in fuel loading was calculated from post burn measurement of the consumption of foliage material.

Burns were conducted for three spread rate treatments. The changes in the rate of spread were obtained in two ways. The low and intermediate spread rate burn treatments were obtained by increasing the slope of the fuel bed. The highest spread rate treatments were obtained in a wind tunnel.

Specimens were placed 1-3 inches from the fuel bed on the soil matrix surface and thermocouples were attached to the surface of each fossil sample. Imagery from a video camera was used to measure the rate of spread and flame angle. Radiant and total heat flux was measured at the soil surface for the low and intermediate rate of spread burns.

Results From Lab Studies

There were no significant fossil type differences present in the surface temperatures of the samples.

Burns #1 and #2 had the lowest rates of spread and flame angles of all of the lab studies (Table 5). Under these conditions, fire had no effect on the study specimens. The fire intensities, flame angles and rates of spread measured were consistent with fire behavior model predictions for the grassland fuel model.

Burn Study #	**Average Maximum Surface Temperature (°C)**	**Temperature Increase (°C)**	**Pre-Burn Ambient Specimen Temperature (°C)**
1	31.86	13.74	18.12
2	31.64	14.11	17.53
3	59.22	40.95	18.27
4	44.61	28.59	18.33
5	493.75	471.5	22.25
6 WT	328.77	304.49	24.28
7 WT	492.33	467.51	24.82

Table 4. Average Surface Temperatures on Fossil Specimens – 2001 Lab Study

Burns #3 and #4 showed rates of spread, intensities and flame angles greater than Burns #1 and #2 (Table 5). No changes in fossil specimen condition were observed. The fire intensities, flame angles and spread rates were consistent with fire behavior model predictions for these conditions.

Burn #5 represented an intermediate spread rate on the grassland /shrub fuel treatment burn where specimens were in contact with fuel. The measured spread rate was similar

to the previous intermediate spread rate burns (Table 5). The fire intensity and flame angle were also similar to the previous intermediate burns. All fossil specimens were covered with tar build up and had significant discoloration (Figure 5). No cracking or splitting was observed.

Burns #6 and #7 represented a high rate of spread/ high intensity burn and were conducted in the wind tunnel with a 3 mph wind. A 10 mph wind speed measured at 20 feet represents a mid-flame wind speed of 3 mph in a grassland fuel type. The fire intensity and flame angle were consistent with model predictions for these conditions. The spread rates, intensity and flame angles were greater than both the low and moderate rate of spread burns (Table 5). Discoloration was found on the fossil surfaces and no cracking or splitting was observed.

The measured radiant surface fluxes were consistent with results from previous testing under similar conditions. The high surface flux of Burn #4 reflects the sensor placement in direct contact with burning fuel.

Burn Study #	Rate of Spread (meters/minute)	Fuel Type	Slope (%)	Wind Speed (mph)	Maximum Radiant Surface flux (kw/cm^^{2}/sec)
1	0.623	G	0	0	25.62
2	0.691	G/S	0	0	45.67
3	2.14	G	39	4-6	32.3
4	2.36	G/S	39	4-6	63.49
5	2.5	G/S	39	4-6	36.76
6 WT	29.1	G	0	3-4	55
7 WT	34.3	G/S	0	3-4	60

Table 5. Rate of Spread, Fuel Loading and Fire Characteristics - 2001 Lab Study

WT - Wind Tunnel

G - Grass

S - Shrub

Discussion of Laboratory Results

No fire effects were found on fossil specimens from the laboratory under low spread rates, low intensities and without physical contact with fuel. In the intermediate burn treatments where the fuel was in contact with the fossil specimens and wind speeds were in the 4-6 mph range, there was an effect on the exposed fossils. In high spread rate /high intensity burns where wind speeds were in the 10 mph range and specimens were located 1-3 inches from the fuel, there was an effect on all exposed fossils.

Rate of spread, intensity, flame angel and flame length are positively correlated with wind speed. Increases in these parameters leads to increased heat transfer from the flame front to the specimen surfaces. Fossils in the high spread rate / high intensity fires were affected even though they were not in direct contact with any fuel. These results suggest that the size of the buffer zone needed to protect the samples was dependent on burning characteristics.

Summary of Field and Laboratory Burns

The data from the field burns conducted during the spring of 2001 show the field burns can be characterized as low rate of spread/ low intensity burns. The estimates of the radiant surface flux of the field burns were lower but were comparable to the surface fluxes measured under low rate of spread/ low intensity laboratory conditions.

The comparison of laboratory and field burn observations suggests that the flame geometries and the radiant surface flux measurements of the field burns were similar to the low intensity laboratory burns. High spread rates and long flame lengths were observed during the field burning but no measurements were taken on sites with high rate of spread/ high intensity conditions.

The most consistent fire effect found in both the field and lab studies was chemical discoloration or “sooting” of the specimens. The interaction of combustion, smoke and surface temperature appeared to create these effects. The data suggest that the interaction between fossil surface temperature and the distance from fuel are important predictors of fire effects on exposed paleontological specimens and that fire geometry plays a key role in these surface temperatures.

While there was no physical damage (cracking or fracturing) to the specimens observed in the laboratory studies, the field studies did show fracturing on one specimen from Ham's Draw #2. Physical damage to native rocks has been observed in fires of grassland/shrub land fuels in a number of studies. In this case, the inconsistency between the laboratory and field results suggests increasing our sample size and increasing the range of burning conditions in the future.

Future Research Questions

As with any research project, many new questions as well as answers are often generated and the following questions are the result of this study.

1) What is the quantitative relationship between burning characteristics such as rate of spread and intensity with levels of resource damage? An improved understanding of the dynamics of fossil protective "buffer zone " size for a range of prescribed and wild fire conditions is needed. The data from these studies is essential to the development of burning prescriptions that minimize expected resource damage. The results of this future study might be applicable to a wide range of resources.

2) Can the measurement and the analysis of the effect of fire on paleontological resources be done more efficiently? New techniques that more accurately and efficiently measure the sample surface temperatures need to be developed for both field and lab work. New measurement techniques could take advantage of infrared camera or non-contact temperature measurement technology.

3) What is the role of smoke and heat in fossil resource damage? The physical processes responsible for the surface discoloration and other effects found in this study and their significance are unknown.

Recommendations

There are paleontological resource management concerns over the use of prescribed fire at Badlands National Park. A number of these concerns could be addressed during fire prescription development. Through the integration of paleontological resource

distributions with practical burning constraints, operational burning plans can be developed that will incorporate firing techniques to minimize expected resource damage. The implementation of burning strategies includes black lining, burning away from important resource areas, and burning sensitive areas with low rates of spread and low intensities. There are a number of simple and effective solutions that would minimize expected resource damage.

List of Figures

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Appendix A

Graphs - field and lab

Appendix B

Budget

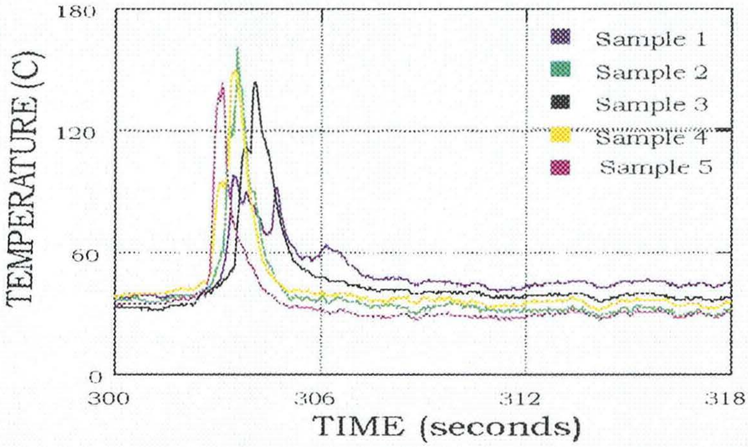
USDA Intermountain Fire Lab	
Travel and per diem for Jim Reardon to travel from Missoula MT to Badlands National Park (2 trips)	3200
Salary for a GS-5 Technician (2 pp)	2000
Materials and Supplies	750
RMRS overhead @ 12%	714
Subtotal	6664
Badlands National Park	
Travel costs to Missoula, Montana from Badlands National Park (1 trip)	2000
Materials and supplies	836
Subtotal	2836
Total	**9500**

Matching Funds from Park and Cooperator:

• Park Paleontologist, GS-11, 6 weeks/yr (NPS, BADL)	8000
• Seasonal Physical Science Tech, GS-5, 6 weeks/yr (NPS, BADL)	3000
Total Matching	**11000**

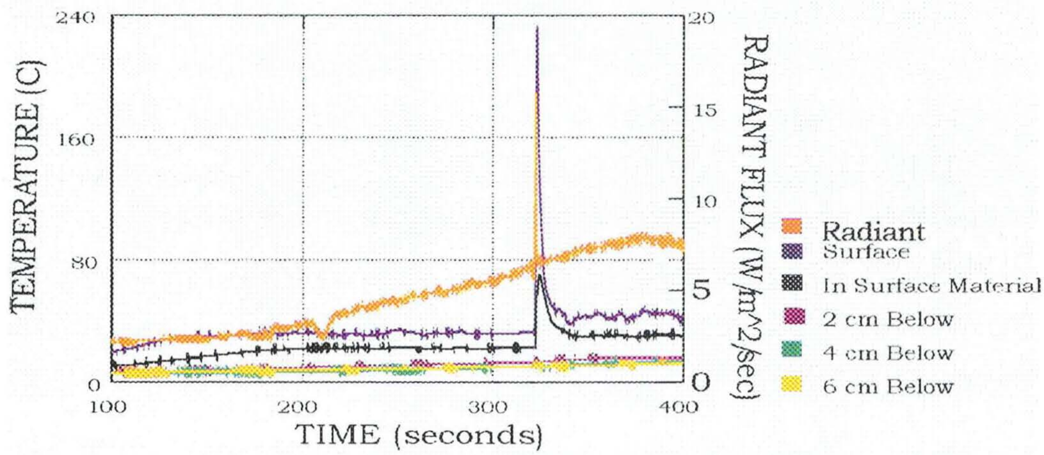
HAMS DRAW 1

FOSSILS



	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Minimum	9	9	9	9	11
Maximum	98	160	144	150	143
Range	89	151	135	141	132

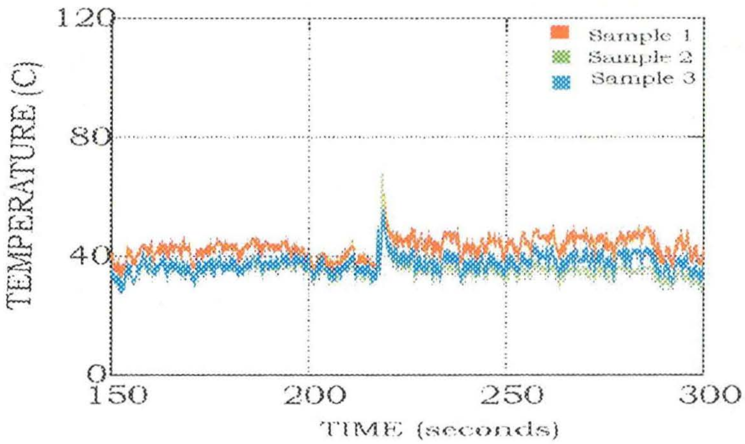
SOIL DEPTHS/HEAT FLUX



	On Surface	In Surface Material	2 cm	4 cm	6 cm	Radiant Flux
Minimum	7	6	6	6	6	1.415
Maximum	232	70	21	20	13	15.808
Range	225	64	15	14	7	14.392

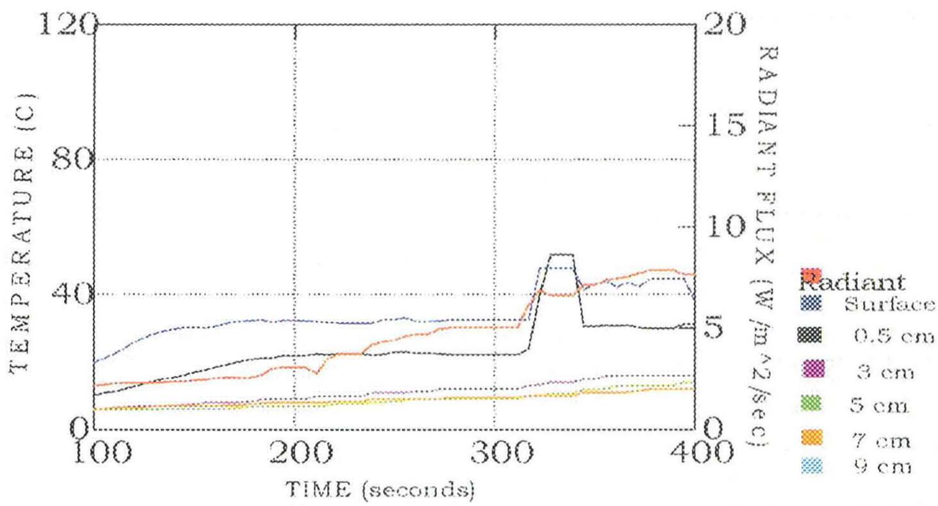
HAMS DRAW 2

FOSSILS



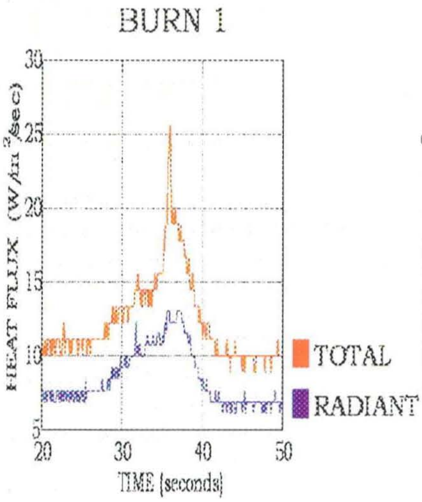
	Sample 1	Sample 2	Sample 3
Minimum	22	15	13
Maximum	61	67	55
Range	39	52	42

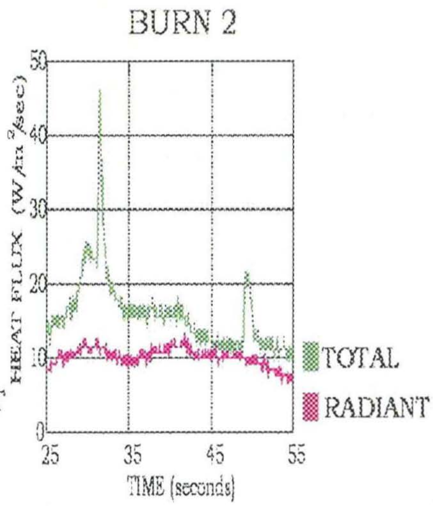
SOIL DEPTHS/HEAT FLUX

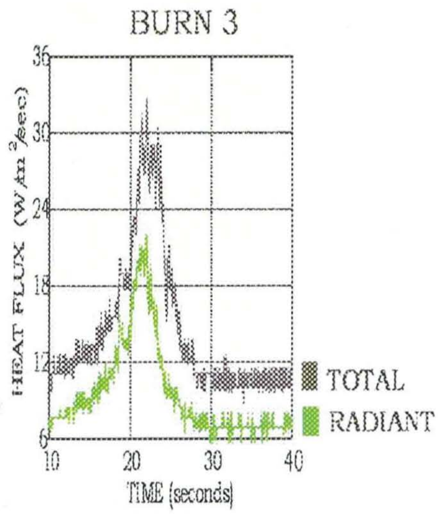


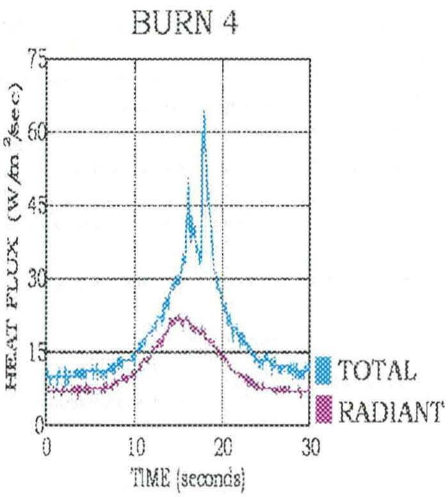
	Surface	0.5 cm	3 cm	5 cm	7 cm	9 cm	Radiant Flux
Minimum	19	13	13	14	13	13	13
Maximum	31	22	22	22	22	19	37
Range	12	9	9	8	9	6	24

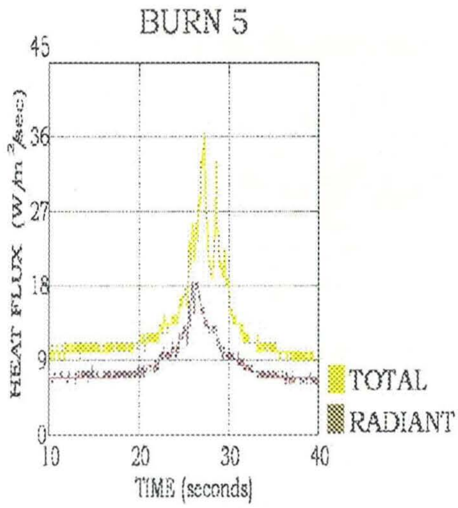
Med Therms







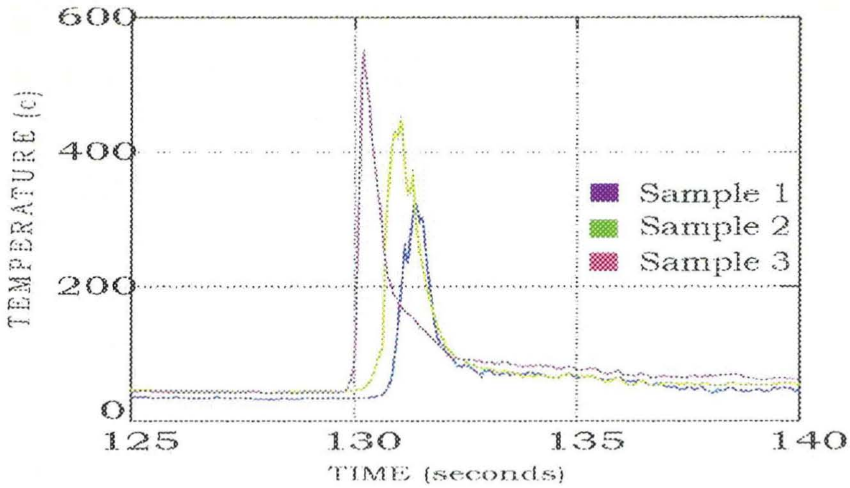




	BURN 1		BURN 2		BURN 3		BURN 4		BURN 5	
	Total	Radiant	Total	Radiant	Total	Radiant	Total	Radiant	Total	Radiant
Minimum	8.91	6.15	8.91	6.15	8.91	6.15	8.91	6.15	7.8	6.15
Maximum	25.62	13.06	45.67	13.06	32.3	21.52	63.49	22.28	36.76	18.44
Range	16.71	6.91	36.76	6.91	23.39	15.37	54.58	16.13	28.96	12.29

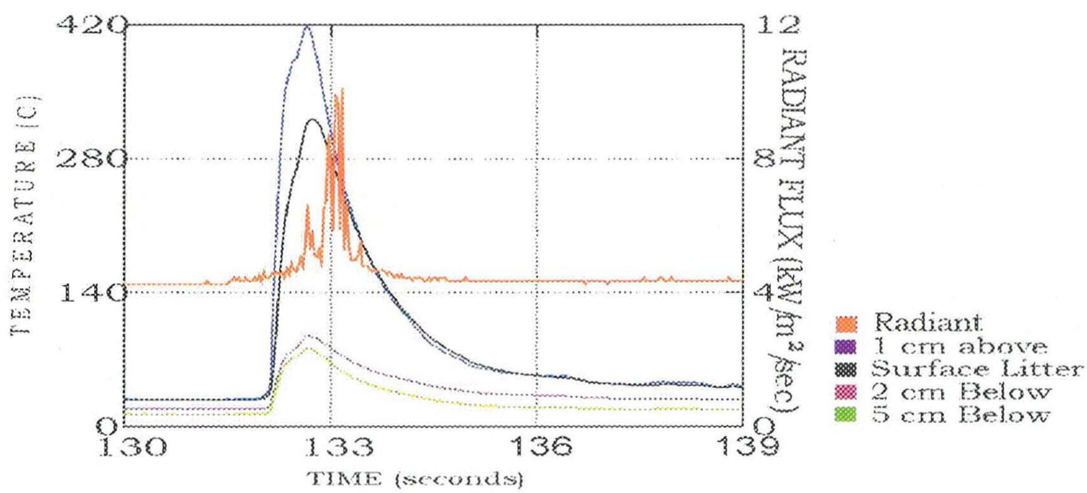
PRAIRIE WIND 1

FOSSIL SAMPLES



	Sample 1	Sample 2	Sample 3
Minimum	20	24	25
Maximum	324	447	547
Range	304	423	522

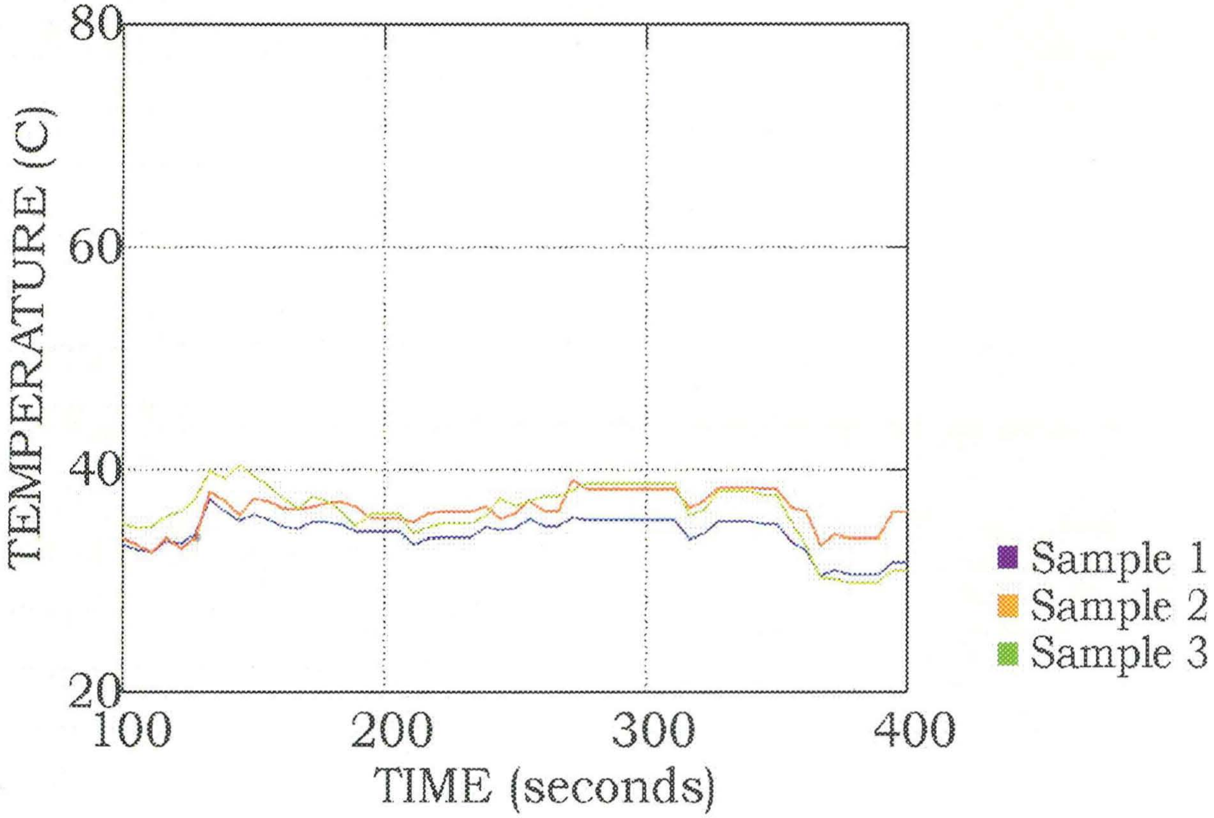
SOIL DEPTHS/HEAT FLUX



	1 cm Above	0.5 cm Below	2 cm Below	5 cm Below	Radiant Flux
Minimum	9	9	10	9	1.798
Maximum	418	321	95	82	10.077
Range	409	312	85	73	8.278
Peak Flux ($kW/m^2/sec$)					10.07

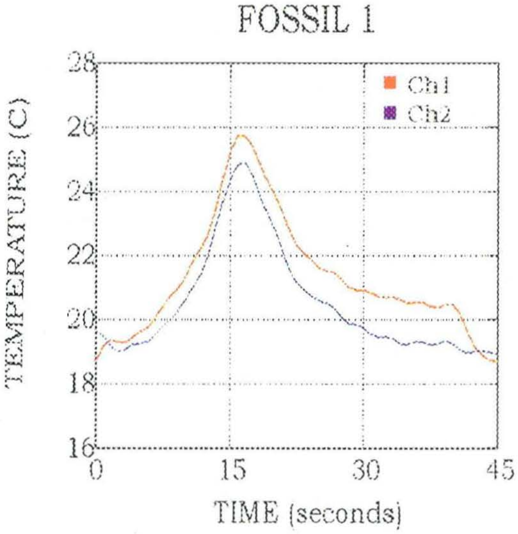
PRAIRIE WIND 2

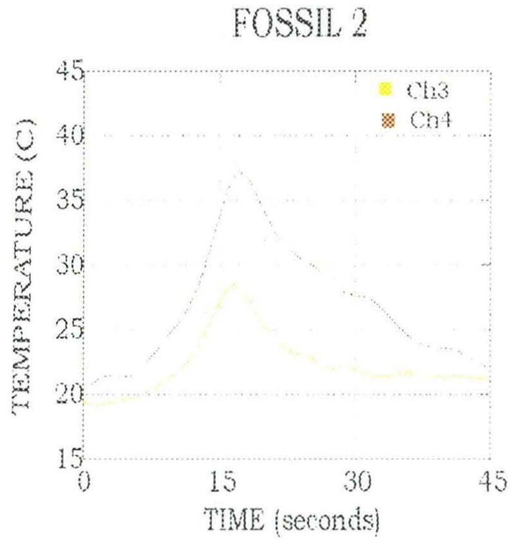
FOSSILS

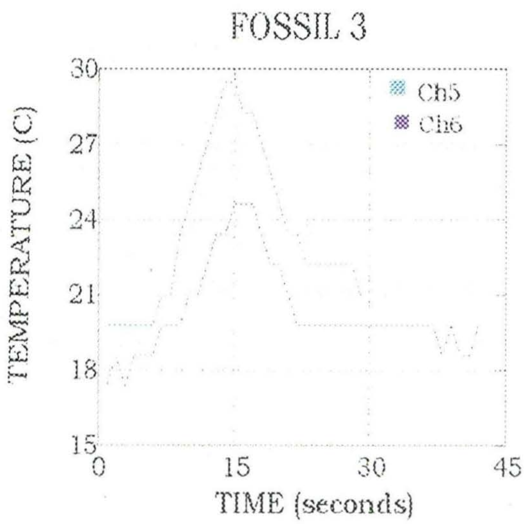


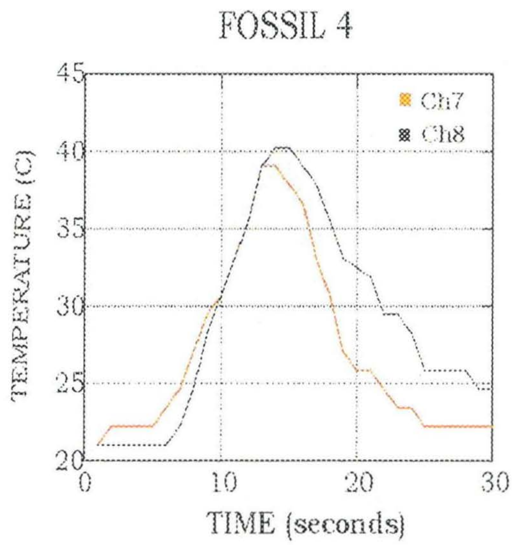
	Sample 1	Sample 2	Sample 3
Minimum	22	24	22
Maximum	45	46	45
Range	23	22	23

BURN 1





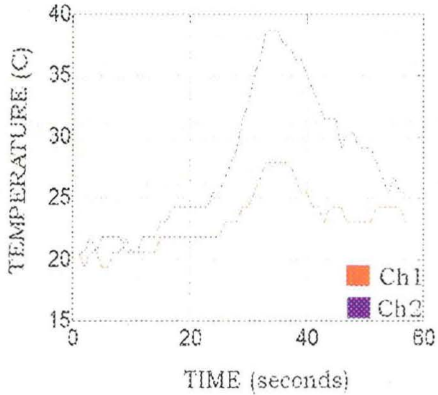




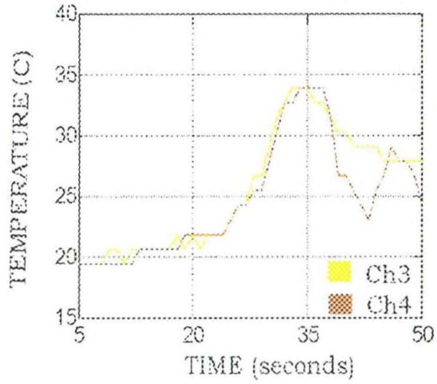
	FOSSIL 1		FOSSIL 2		FOSSIL 3		FOSSIL 4	
	Channel 1	Channel 2	Channel 3	Channel 4	Channel 5	Channel 6	Channel 7	Channel 8
Minimum	17.36	17.36	18.58	18.58	17.36	17.36	19.79	18.58
Maximum	27.06	25.85	29.47	39.06	24.64	29.47	39.06	40.25
Range	9.7	8.49	10.89	20.48	7.28	12.11	19.27	21.67

BURN 2

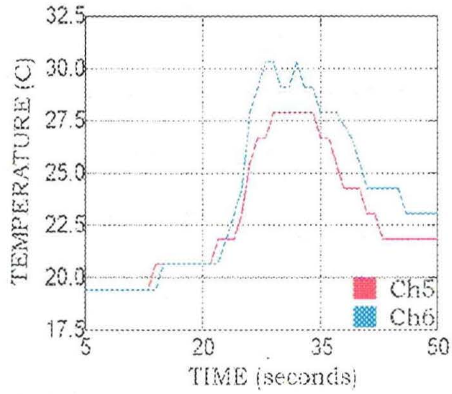
FOSSIL 1



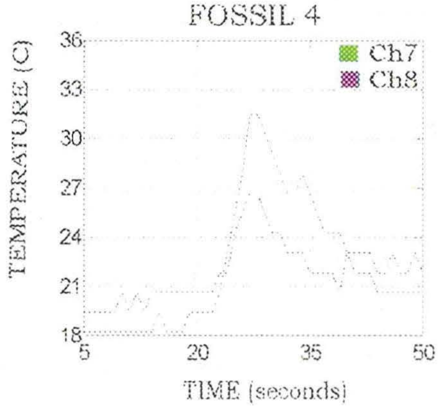
FOSSIL 2



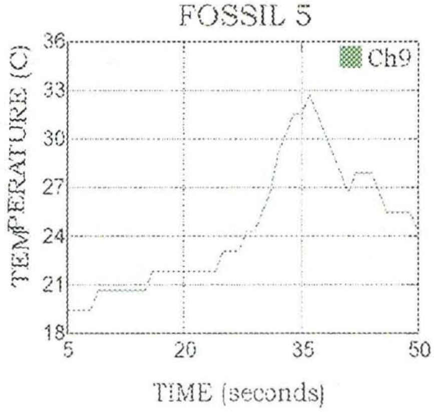
FOSSIL 3



FOSSIL 4

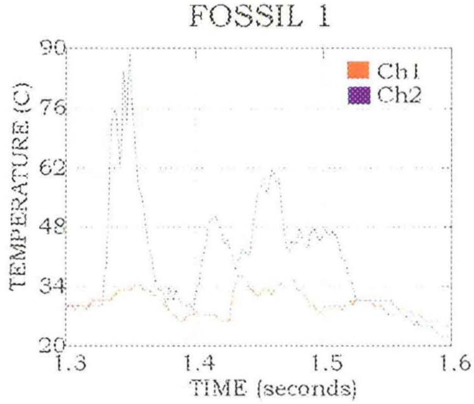


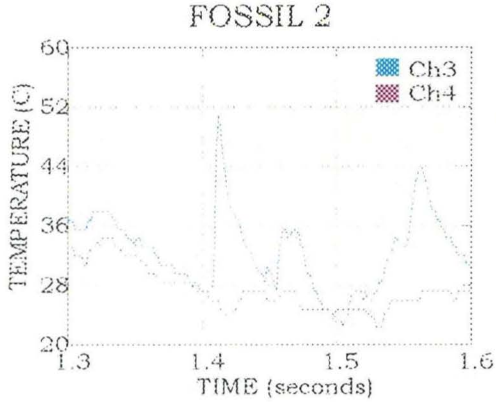
FOSSIL 5

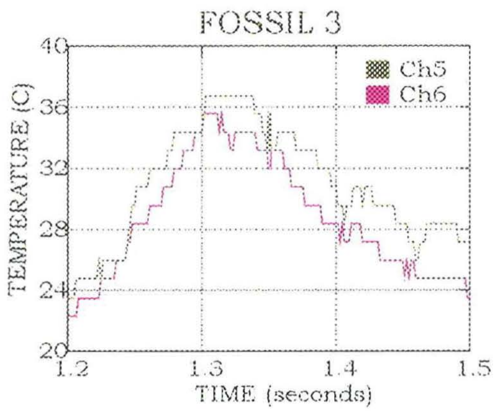


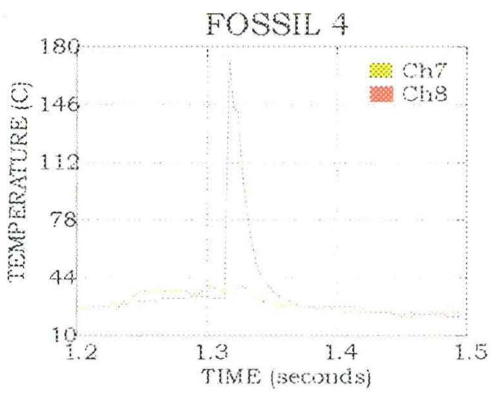
	FOSSIL 1		FOSSIL 2		FOSSIL 3		FOSSIL 4		FOSSIL 5
	Channel 1	Channel 2	Channel 3	Channel 4	Channel 5	Channel 6	Channel 7	Channel 8	Channel 9
Minimum	16.99	18.21	19.42	16.99	18.21	16.99	15.77	16.99	18.21
Maximum	27.9	38.7	33.91	35.11	27.9	30.31	31.51	26.69	32.71
Range	10.91	20.49	14.49	18.12	9.69	13.32	15.74	9.7	14.5

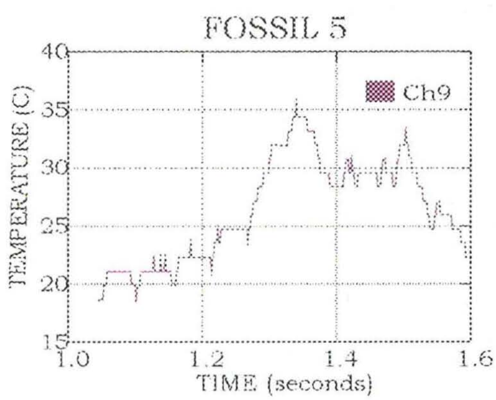
BURN 3







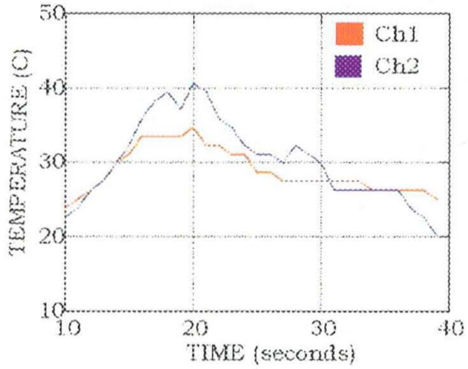




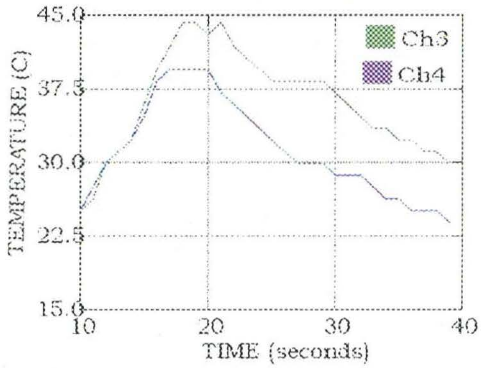
	FOSSIL 1		FOSSIL 2		FOSSIL 3		FOSSIL 4		FOSSIL 5
	Channel 1	Channel 2	Channel 3	Channel 4	Channel 5	Channel 6	Channel 7	Channel 8	Channel 9
Minimum	17.46	18.68	18.68	17.46	18.68	17.46	18.68	18.68	18.68
Maximum	37.97	88.65	52.22	34.38	35.58	36.77	40.36	171.48	35.58
Range	20.51	69.97	33.54	16.92	16.9	19.31	21.68	152.8	16.9

BURN 4

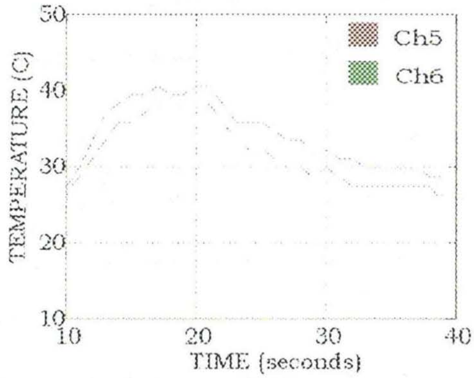
FOSSIL 1



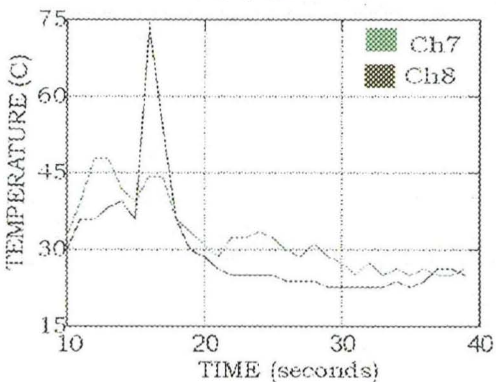
FOSSIL 2



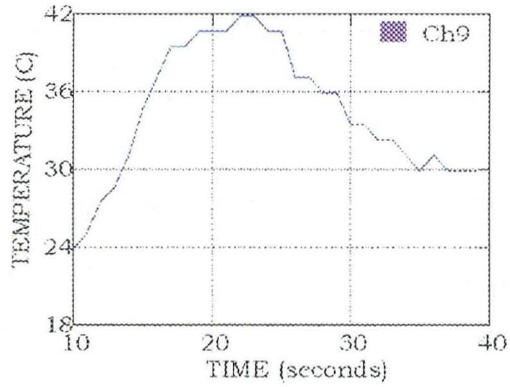
FOSSIL 3



FOSSIL 4

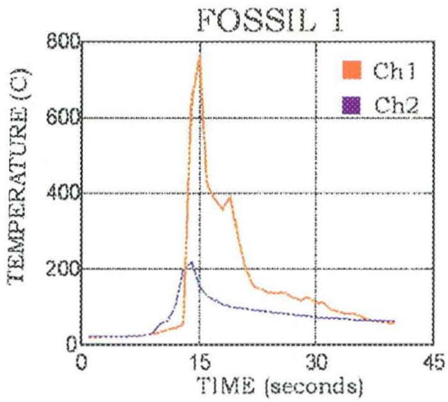


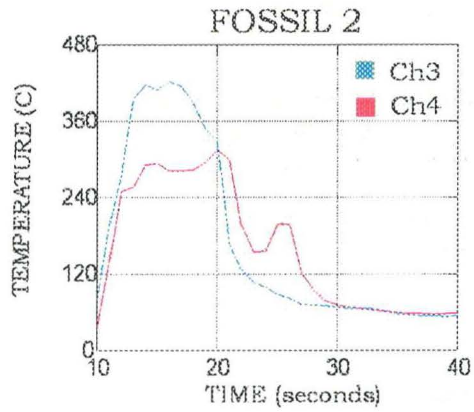
FOSSIL 5

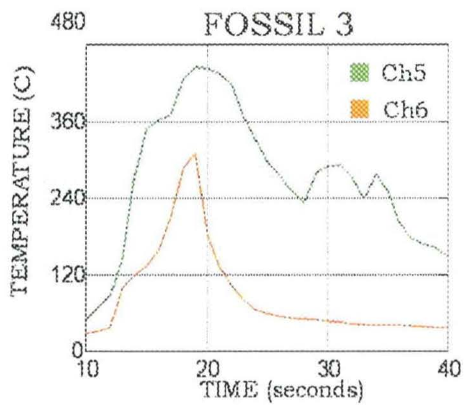


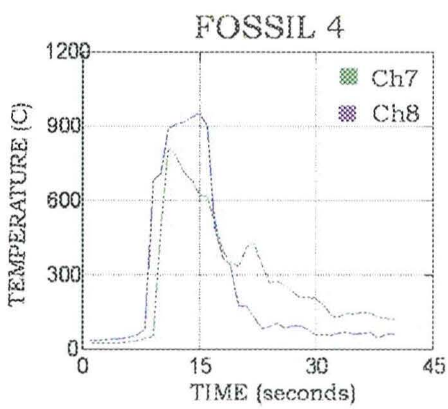
	FOSSIL 1		FOSSIL 2		FOSSIL 3		FOSSIL 4		FOSSIL 5
	Channel 1	Channel 2	Channel 3	Channel 4	Channel 5	Channel 6	Channel 7	Channel 8	Channel 9
Minimum	19.01	17.79	19.01	17.79	19.01	17.79	17.79	19.01	17.79
Maximum	34.7	40.67	44.25	39.48	38.29	40.67	47.81	73.71	41.87
Range	15.69	43.69	25.24	21.69	19.28	22.88	30.02	54.7	24.08

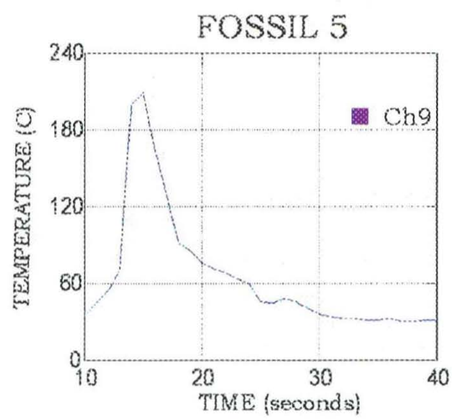
BURN 5





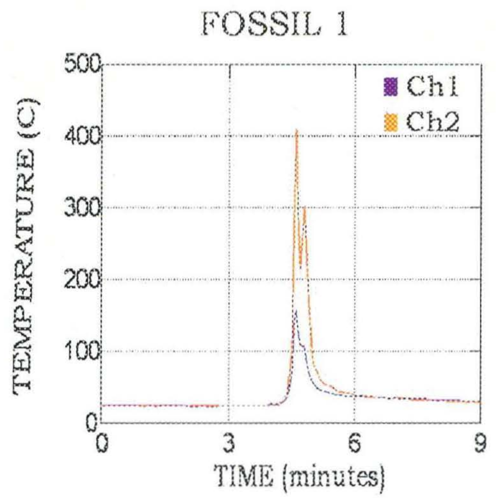


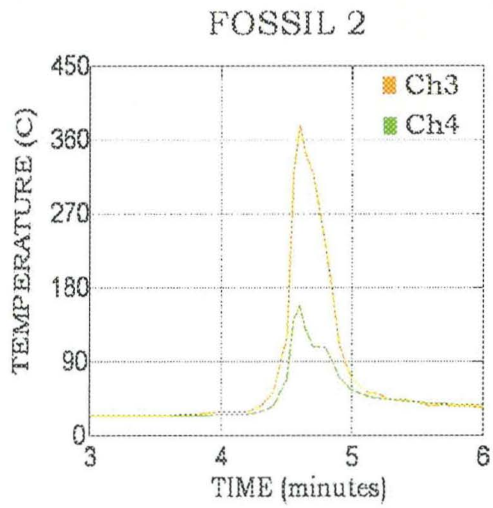


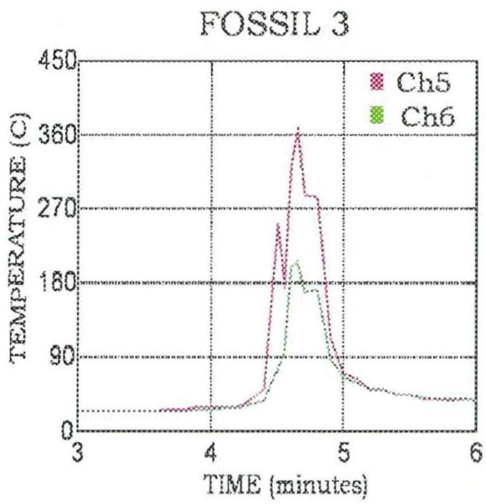


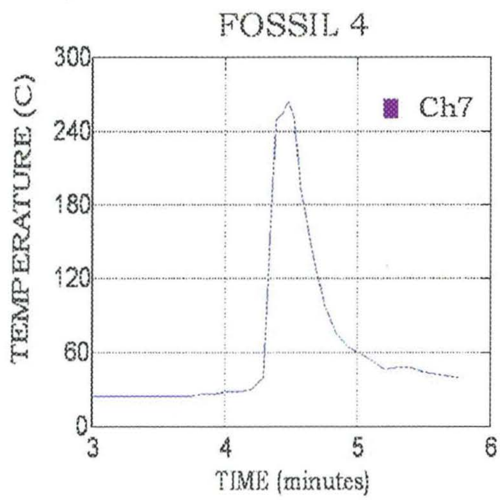
	FOSSIL 1		FOSSIL 2		FOSSIL 3		FOSSIL 4		FOSSIL 5
	Channel 1	Channel 2	Channel 3	Channel 4	Channel 5	Channel 6	Channel 7	Channel 8	Channel 9
Minimum	20.51	21.72	21.72	20.51	19.29	21.72	21.72	32.58	20.51
Maximum	762.43	218.39	421.9	313.83	311.48	440.32	813.51	953.26	208.66
Range	741.92	196.67	400.18	293.32	292.19	418.6	791.79	920.68	188.15

BURN 6



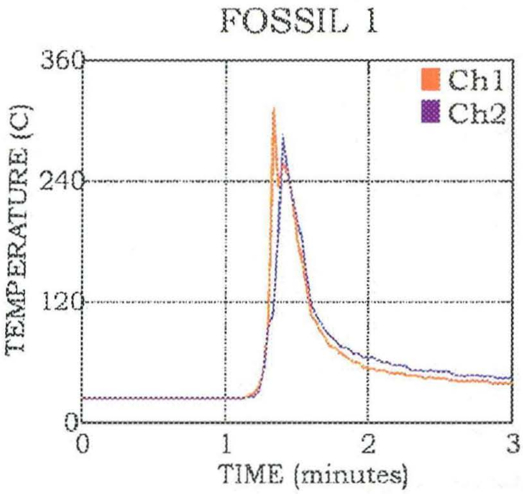


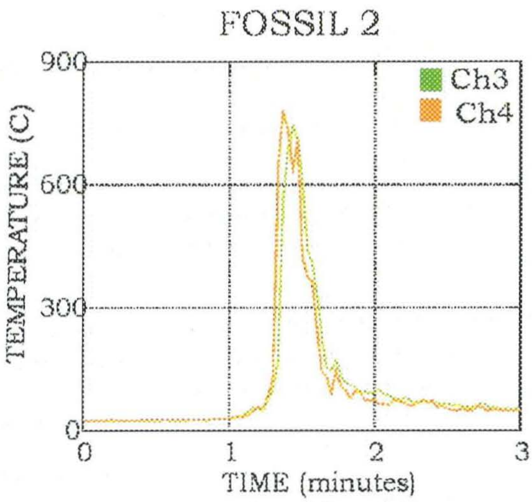


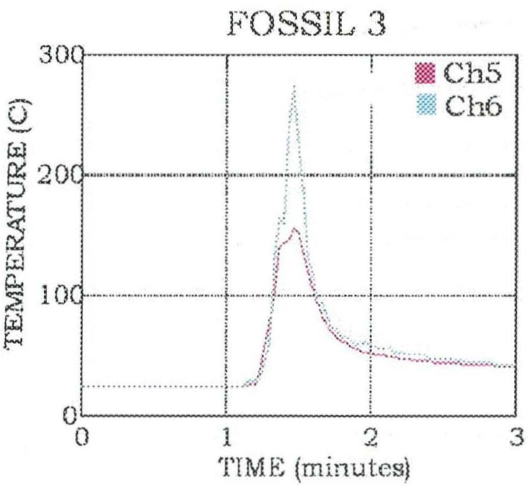


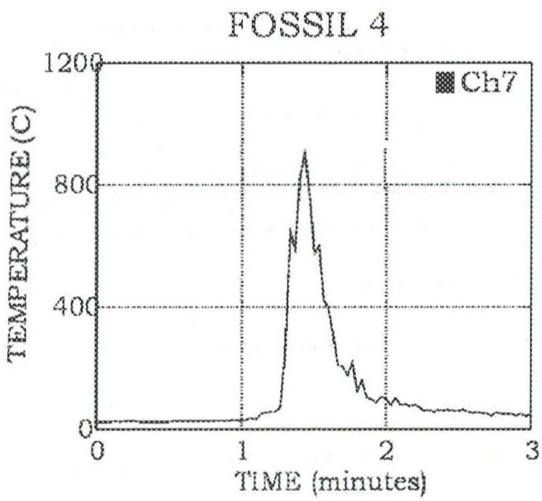
	FOSSIL 1		FOSSIL 2		FOSSIL 3		FOSSIL 4
	Channel 1	Channel 2	Channel 3	Channel 4	Channel 5	Channel 6	Channel 7
Minimum	24.73	24.73	23.14	24.76	24.76	23.14	24.73
Maximum	520.7	409	158.4	378.8	366.1	205.3	263.1
Range	495.97	384.27	135.26	354.04	341.34	182.16	238.37

BURN 7









	FOSSIL 1		FOSSIL 2		FOSSIL 3		FOSSIL 4
	Channel 1	Channel 2	Channel 3	Channel 4	Channel 5	Channel 6	Channel 7
Minimum	24.82	24.82	24.82	24.82	24.82	24.82	24.82
Maximum	308.6	282.7	745	776	155.1	272.9	906
Range	283.78	257.88	720.18	751.18	130.28	248.08	881.18

United States Department of Agriculture | **Forest Service** | **Rocky Mountain Research Station** | **1730 Samco Road Rapid City, SD 57701 605/394-1960**

File Code: 2060

Date: May 10, 2002

Subject: 28-CR7-966 Eclogical Plant Classification and Monitroring

To: Yahida R Salazar
Grants and Agreements
Rocky Mountain Research Station
240 West Prospect Road
Ft. Collins, CO. 80526

Enclosed are two copies of the final report for the above agreement. If you need additional information, please advise.

Again, thank you.

Daniel W Uresk

DANIEL W. URESK
Project Leader

Library Copy